3. RECYCLED URANIUM MASS FLOW

3.1 Uranium Recycle Description

A diagram to illustrate the RU material mass flow at PORTS is shown in Figure 3.1-1. The total quantity received from each source and the total quantity shipped to each receiver is shown. The center of the diagram represents the several processes the RU material may have passed through after receipt. There is a large difference between the quantity received and the quantity shipped. This difference is due to the diluting nature of the processes at PORTS. When RU is fed to the cascade, the quantity fed is only a small fraction of the total amount of uranium present in the cascade. Once fed, the RU is mixed with the other material already present, and can no longer be tracked based upon the original uranium content. Each constituent is separated from the original uranium and follows a different path through the PORTS cascade and other facilities. Therefore, PORTS tracks RU only until it loses it's unique identity; from that point, PORTS tracks each constituent of TRU and ^{99}Tc individually to show the constituents' mass flow and to perform a mass balance.

Recycled uranium was first introduced at PORTS in FY 1955 as UF_6 feed manufactured at Paducah from UO_3 received from Hanford (HRT) and Savannah River (SRT) reactor tails. Also in FY 1955 PPF was provided for PORTS feed. The PPF was contaminated with ^{99}Tc at an estimated 1 ppm (Ref. 2). The UO_3 from HRT/SRT was contaminated with Np, Pu, and ^{99}Tc at an estimated 0.24 ppm, 4 ppb, and 7 ppm, respectively, prior to FY 1967 and 0.09 ppm, 2.2 ppb, and 7 ppm, respectively, thereafter (Ref. 2). After feed was manufactured from the HRT/SRT oxide it was contaminated with Np, Pu, and ^{99}Tc at an estimated 0.18 ppm, 0.04 ppb, and 6.65 ppm, respectively, prior to FY 1967 and 0.068 ppm, 0.021 ppb, and 6.65 ppm, respectively, thereafter (Refs. 2 and 2a).

To illustrate and track the movement of RU, TRU and ^{99}Tc through PORTS, four campaigns which cover all significant events at PORTS from startup in FY 1955 through March 31, 1999 were developed. Each campaign addresses a specific grouping of RU for a specific time period.

The Depleted Reactor Tails – Campaign #1 (Figure 3.1-2), addresses feed manufactured from HRT/SRT oxide and PPF from FY 1955 through FY 1967. The Depleted Reactor Tails – Campaign #2 (Figure 3.1-3) addresses feed manufactured from HRT/SRT oxide and PPF from FY 1968 through March 31, 1999. Note: The bars which extend beyond FY 1978 are assumed to remain constant through March 1999. The Non-UF_6 RU Program – Campaign #3 (Figure 3.1-4) deals with RU of all forms of uranium at PORTS other than UF_6. These campaigns do not include 4.6 MTU of non-UF_6 potentially utilized for development activities in FY 1957. The remaining RU is captured in the UF_6 feed as Miscellaneous Cascade Feed - Campaign #4 (Figure 3.1-5).

Each campaign shows what is known, estimated or projected regarding RU. Each figure identifies the source of the RU, year(s) received at PORTS, quantity of RU, which process(es) the RU, TRU and ^{99}Tc passed through, and when the material was shipped from PORTS. Significant events that occurred during the period are shown. This method allows for a tabulation of the TRU and ^{99}Tc by year to provide a year-end inventory, and establishes the RU constituent inventory as of March 31, 1999.

The RU, containing TRU and ^{99}Tc, was first introduced between FY 1955 and FY 1958 when approximately 527 MTU of feed manufactured from HRT/SRT oxide was received. This material is estimated to have contained a total of 95g Np, 0.021g Pu, and 3.7kg ^{99}Tc . Also, Paducah feed was utilized beginning in FY 1955 and continues to the present time. Between FY 1955 and FY 1971, ^{99}Tc was present at a concentration of approximately 1 ppm. During this time, 43.5 kg of ^{99}Tc is estimated to have been fed into the PORTS cascade. To establish the annual inventory of ^{99}Tc from Paducah feed, the total quantity received during this period was distributed evenly over the 17-year period. Various sections of this report discuss in detail specific plant facilities which processed/concentrated RU, TRU, and ^{99}Tc and will not be repeated here except as required to describe the flow of the RU and its constituents through each campaign.

3.1.1 Campaign #1

During Campaign #1, the TRU and ^{99}Tc contaminants that entered the cascade with feed manufactured from HRT/SRT oxide and early PPF were substantially removed during the first cascade change-out program. It is assumed that during this period, material was fed upon receipt and the empty cylinders with heels were returned to Paducah/Oak Ridge. These cylinders were not cleaned at PORTS; therefore, any TRU, RU, and ^{99}Tc contained in the heels went to Paducah or Oak Ridge.

Figures 3.1-1

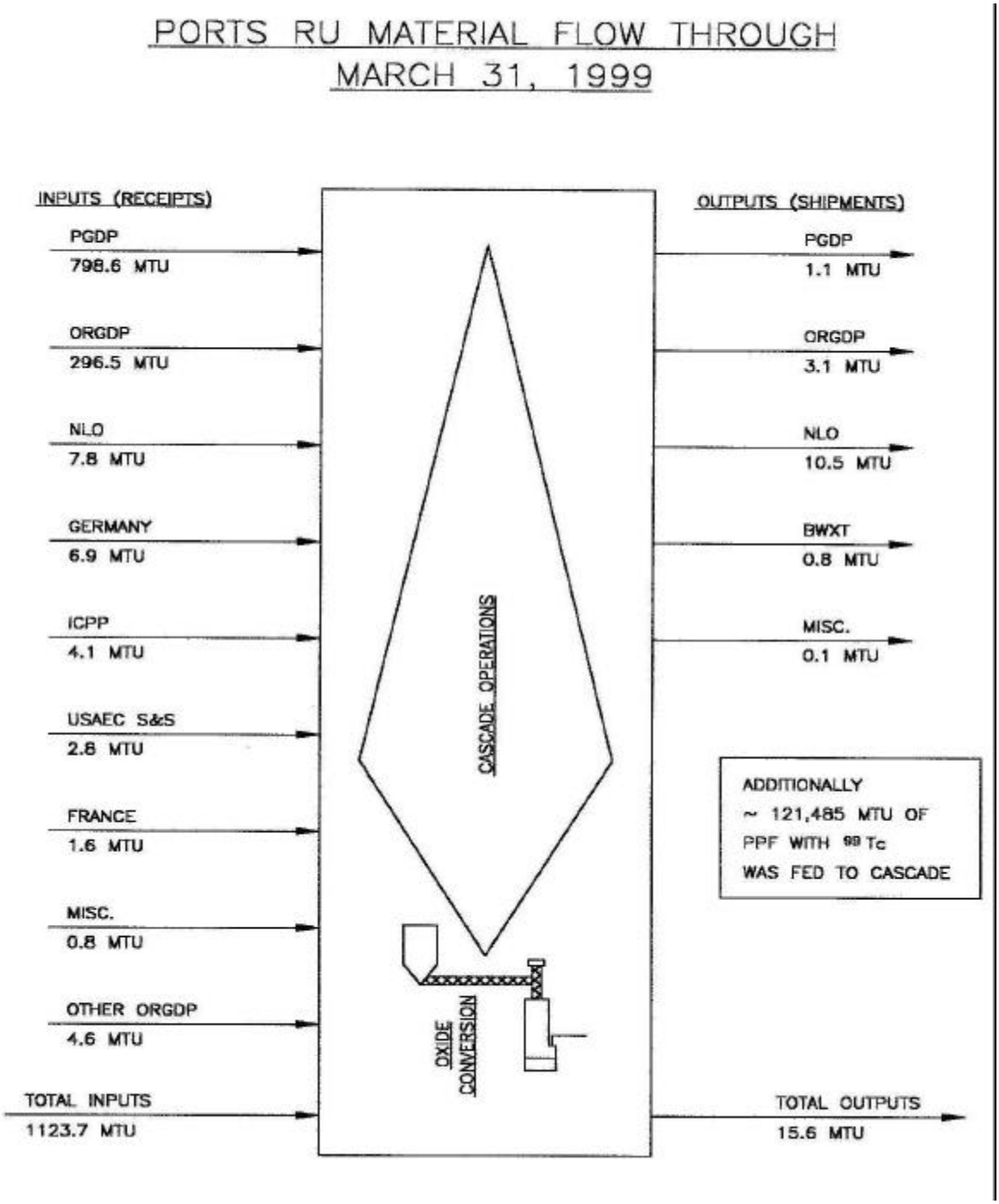


Figure 3.1-2

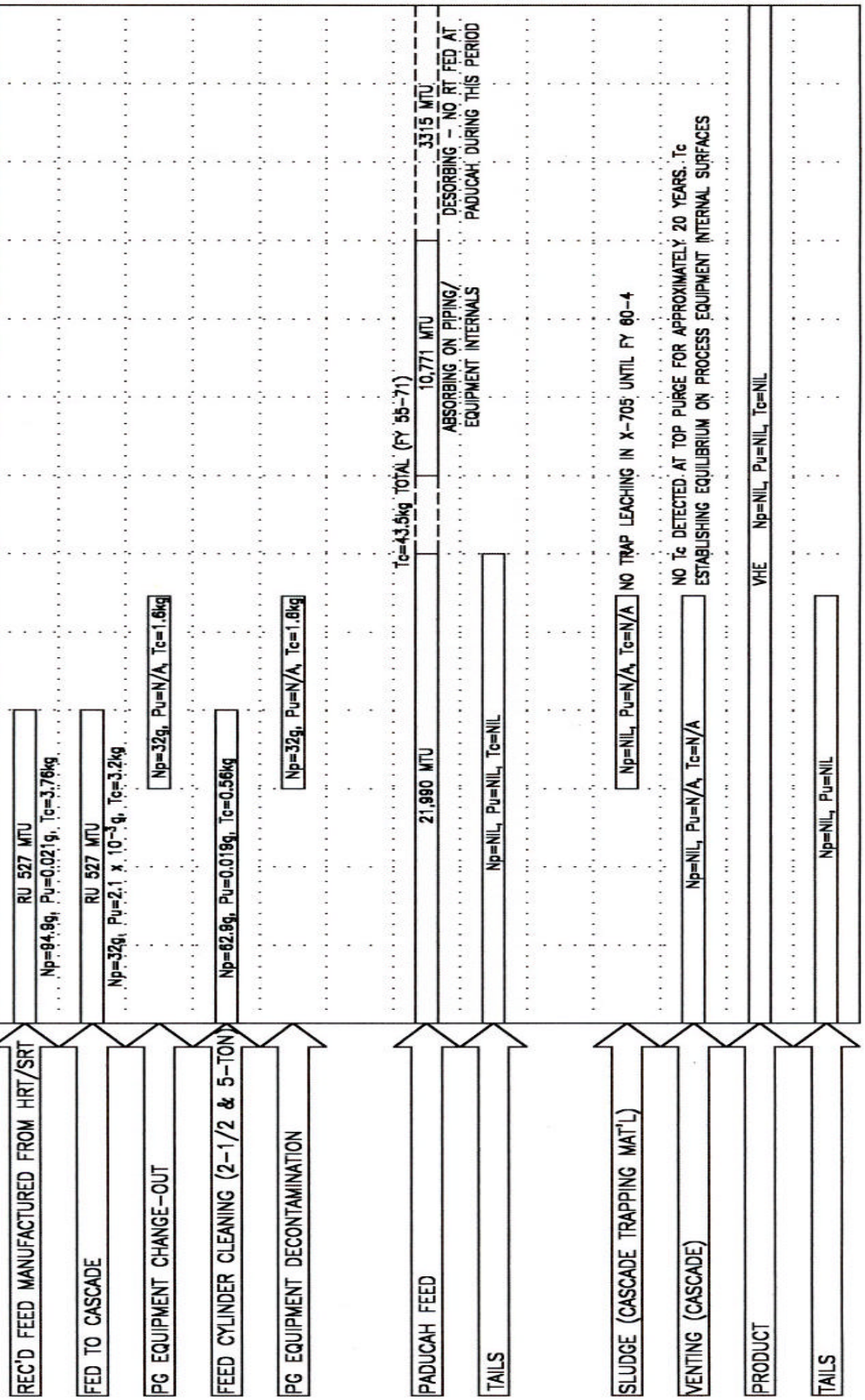

DEPLETED REACTOR TAILS
CAMPAIGN #1
FY 55
FY 56
FY 57
FY 58
FY 59
FY 60
FY 61
FY 62
FY 63
FY 64
FY 65
FY 66
FY 67
REC'D FEED MANUFACTURED FROM HRT/SRT
RU 527 MTU
Np=94.9g, Pu=0.021g, Tc=3.76kg
FED TO CASCADE
RU 527 MTU
Np=32g, Pu=2.1 x 10⁻³g, Tc=3.2kg
PG EQUIPMENT CHANGE-OUT
Np=32g, Pu=N/A, Tc=1.6kg
FEED CYLINDER CLEANING (2-1/2 & 5-TON)
Np=62.9g, Pu=0.019g, Tc=0.56kg
PG EQUIPMENT DECONTAMINATION
Np=32g, Pu=N/A, Tc=1.8kg
Tc=43.5kg TOTAL (FY '55-'71)
PADUCAH FEED
21,990 MTU
10,771 MTU
3315 MTU
ABSORBING ON PIPING/ EQUIPMENT INTERNALS
DESORBING - NO RT FED AT PADUCAH DURING THIS PERIOD
TAILS
Np=NIL, Pu=NIL, Tc=NIL
SLUDGE (CASCADE TRAPPING MAT'L)
Np=NIL, Pu=N/A, Tc=N/A
NO TRAP LEACHING IN X-705 UNTIL FY 60-4
VENTING (CASCADE)
Np=NIL, Pu=N/A, Tc=N/A
NO Tc DETECTED AT TOP PURGE FOR APPROXIMATELY 20 YEARS. Tc ESTABLISHING EQUILIBRIUM ON PROCESS EQUIPMENT INTERNAL SURFACES
PRODUCT
VHE Np=NIL, Pu=NIL, Tc=NIL
TAILS
Np=NIL, Pu=NIL

Figure 3.1-3

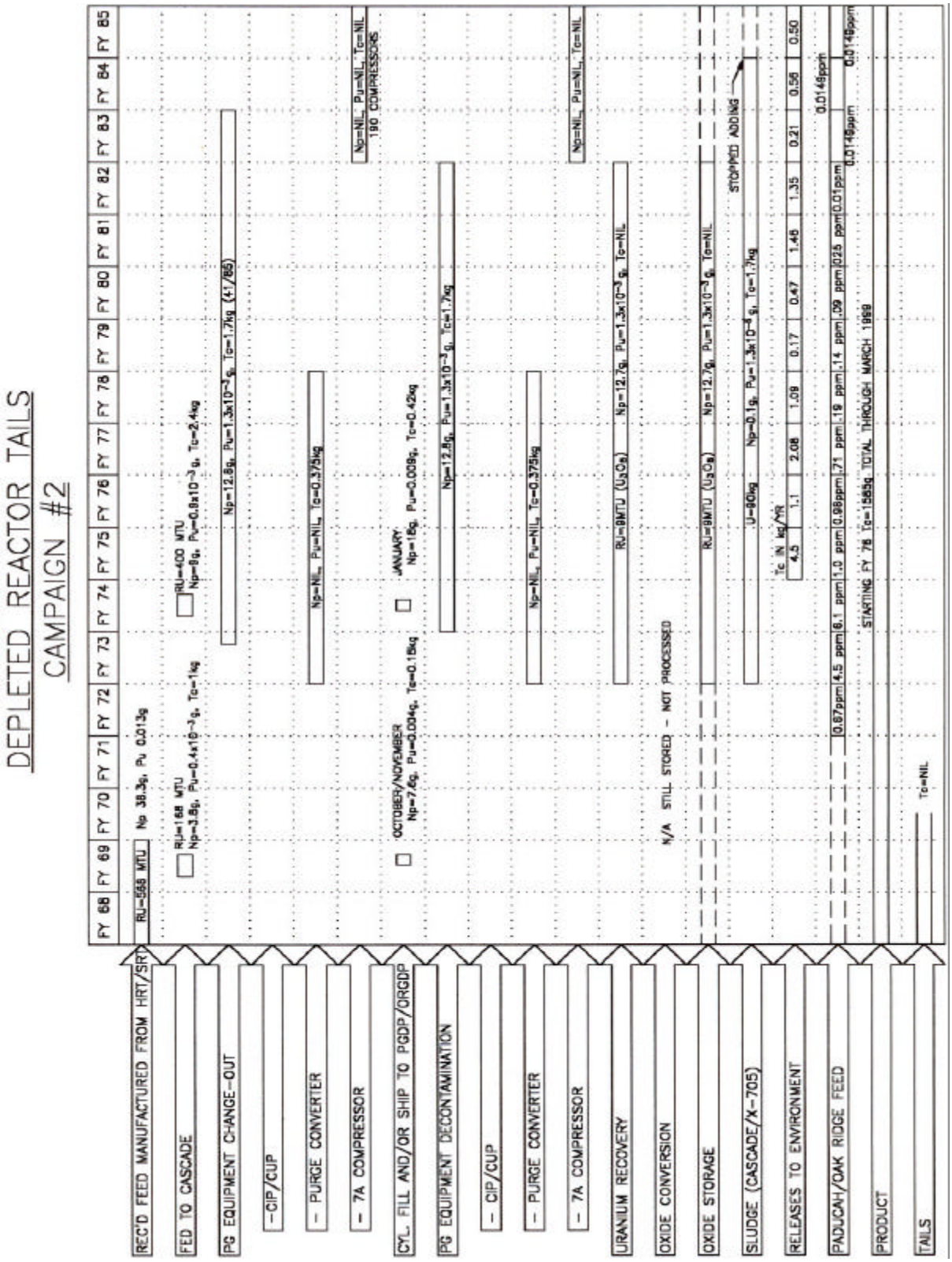

DEPLETED REACTOR TAILS
CAMPAIGN #2
FY 68
FY 69
FY 70
FY 71
FY 72
FY 73
FY 74
FY 75
FY 76
FY 77
FY 78
FY 79
FY 80
FY 81
FY 82
FY 83
FY 84
FY 85
REC'D FEED MANUFACTURED FROM HRT/SRP
RU=568 MTU
No 38.3g, Pu 0.013g
FED TO CASCADE
RU=168 MTU
Np=3.8g, Pu=0.4x10⁻³g, Tc=1kg
RU=400 MTU
Np=8g, Pu=0.8x10⁻³g, Tc=2.4kg
PG EQUIPMENT CHANGE-OUT
Np=12.8g, Pu=1.3x10⁻³g, Tc=1.7kg (41/85)
-CIP/CUP
- PURGE CONVERTER
Np=NIL, Pu=NIL, Tc=0.375kg
- 7A COMPRESSOR
Np=NIL, Pu=NIL, Tc=NIL
190 COMPRESSORS
CYL. FILL AND/OR SHIP TO PGDP/ORGDP
OCTOBER/NOVEMBER
Np=7.6g, Pu=0.004g, Tc=0.15kg
JANUARY
Np=18g, Pu=0.009g, Tc=0.42kg
PG EQUIPMENT DECONTAMINATION
Np=12.8g, Pu=1.3x10⁻³g, Tc=1.7kg
- CIP/CUP
- PURGE CONVERTER
Np=NIL, Pu=NIL, Tc=0.375kg
- 7A COMPRESSOR
Np=NIL, Pu=NIL, Tc=NIL
URANIUM RECOVERY
RU=8MTU (U3O8)
Np=12.7g, Pu=1.3x10⁻³g, Tc=NIL
OXIDE CONVERSION
N/A STILL STORED - NOT PROCESSED
OXIDE STORAGE
RU=8MTU (U3O8)
Np=12.7g, Pu=1.3x10⁻³g, Tc=NIL
SLUDGE (CASCADE/X-705)
U-80kg
Np=0.1g, Pu=1.3x10⁻⁴g, Tc=1.7kg
STOPPED ADDING
Tc IN kg/YR
4.5
1.1
2.08
1.09
0.17
0.47
1.48
1.35
0.21
0.56
0.50
RELEASES TO ENVIRONMENT
PADUCAH/OAK RIDGE FEED
0.67ppm
4.5 ppm
6.1 ppm
1.0 ppm
0.98ppm
.71 ppm
.19 ppm
.14 ppm
.09 ppm
.025 ppm
0.01ppm
0.0148ppm
0.0148ppm
0.0148ppm
PRODUCT
STARTING FY 78 Tc=1585g TOTAL THROUGH MARCH 1989
TAILS
Tc=NIL

Figure 3.1-4

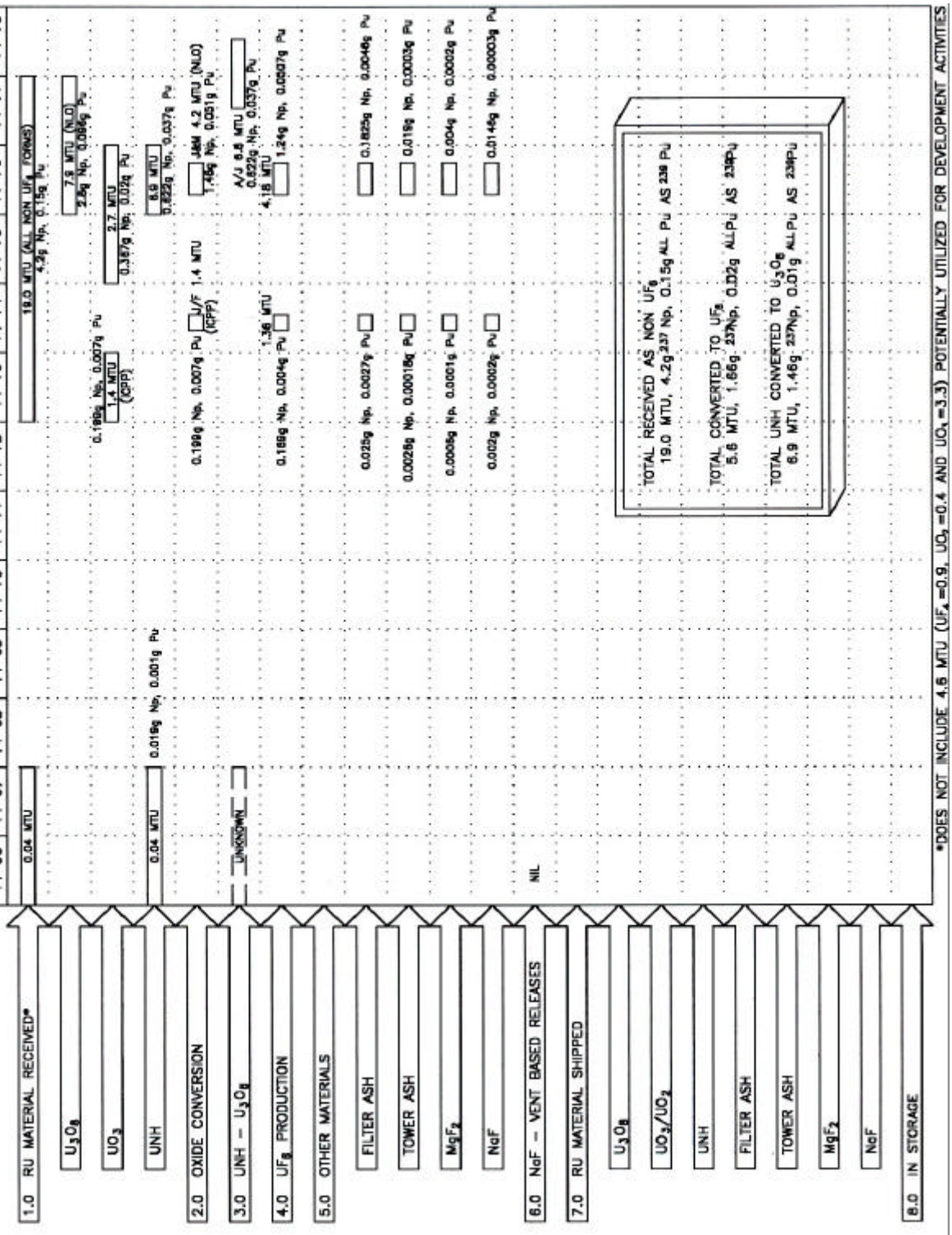
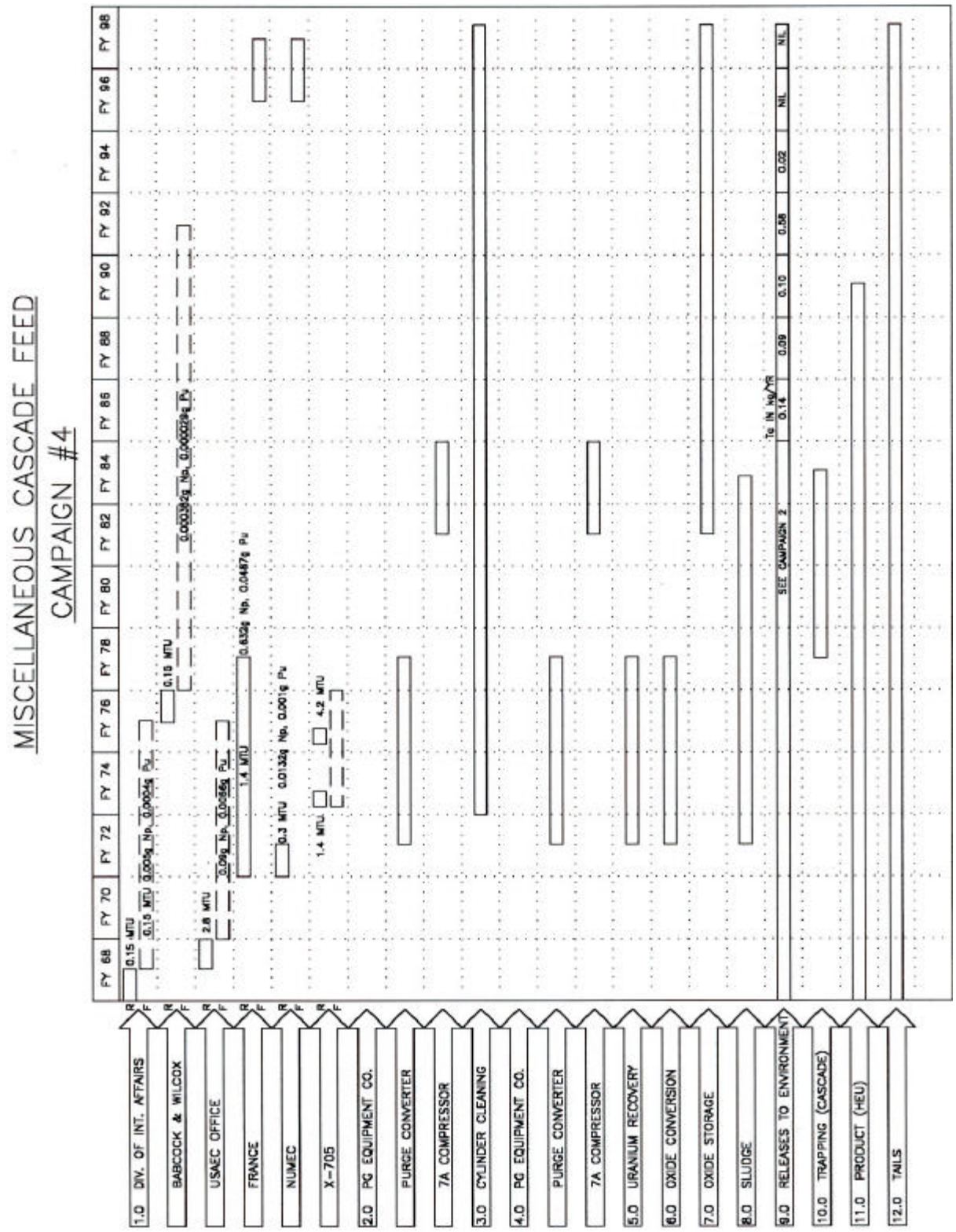

NON–UF6 RU PROGRAM CAMPAIGN #3
FY 66
FY 67
FY 68
FY 69
FY 70
FY 71
FY 72
FY 73
FY 74
FY 75
FY 76
FY 77
FY 78
1.0 RU MATERIAL RECEIVED*
0.04 MTU
19.0 MTU (ALL NON UF6 FORMS)
4.2g Np, 0.15g Pu
U3O8
7.6 MTU (NLO)
2.5g Np, 0.06g Pu
0.189g Np, 0.007g Pu
1.4 MTU (DPP)
UO3
2.7 MTU
0.367g Np, 0.02g Pu
UNH
0.04 MTU
0.018g Np, 0.001g Pu
6.9 MTU
0.822g Np, 0.037g Pu
2.0 OXIDE CONVERSION
0.199g Np, 0.007g Pu
U/F 1.4 MTU (DPP)
464 4.2 MTU (NLO)
1.46g Np, 0.051g Pu
3.0 UNH – U3O8
UNKNOWN
A/U 6.8 MTU
0.822g Np, 0.037g Pu
4.0 UF6 PRODUCTION
1.36 MTU
0.189g Np, 0.004g Pu
4.18 MTU
1.24g Np, 0.0507g Pu
5.0 OTHER MATERIALS
FILTER ASH
0.025g Np, 0.0027g Pu
0.1825g Np, 0.0046g Pu
TOWER ASH
0.0026g Np, 0.00018g Pu
0.018g Np, 0.0003g Pu
MgF2
0.0005g Np, 0.0001g Pu
0.004g Np, 0.0002g Pu
NaF
0.002g Np, 0.0002g Pu
0.0144g Np, 0.00003g Pu
6.0 NaF – VENT BASED RELEASES
NIL
7.0 RU MATERIAL SHIPPED
U3O8
UO2/UO2
UNH
FILTER ASH
TOWER ASH
MgF2
NaF
8.0 IN STORAGE
TOTAL RECEIVED AS NON UF6
19.0 MTU, 4.2g 237Np, 0.15g ALL Pu AS 238 Pu
TOTAL CONVERTED TO UF6
5.8 MTU, 1.66g 237Np, 0.02g ALL Pu AS 238Pu
TOTAL UNH CONVERTED TO U3O8
6.9 MTU, 1.46g 237Np, 0.01g ALL Pu AS 238Pu
*DOES NOT INCLUDE 4.6 MTU (UF4=0.9, UO2=0.4 AND UO4=3.3) POTENTIALLY UTILIZED FOR DEVELOPMENT ACTIVITIES

Figure 3.1-5


MISCELLANEOUS CASCADE FEED
CAMPAIGN #4
FY 68
FY 70
FY 72
FY 74
FY 76
FY 78
FY 80
FY 82
FY 84
FY 86
FY 88
FY 90
FY 92
FY 94
FY 96
FY 98
1.0 DIV. OF INT. AFFAIRS
BABCOCK & WILCOX
USAEC OFFICE
FRANCE
NUMEC
X-705
2.0 PG EQUIPMENT CO.
PURGE CONVERTER
7A COMPRESSOR
3.0 CYLINDER CLEANING
4.0 PG EQUIPMENT CO.
PURGE CONVERTER
7A COMPRESSOR
5.0 URANIUM RECOVERY
6.0 OXIDE CONVERSION
7.0 OXIDE STORAGE
8.0 SLUDGE
9.0 RELEASES TO ENVIRONMENT
10.0 TRAPPING (CASCADE)
11.0 PRODUCT (HEU)
12.0 TAILS
0.15 MTU
0.15 MTU
2.8 MTU
1.4 MTU
0.3 MTU
1.4 MTU
4.2 MTU
0.10 MTU
SEE CAMPAIGN 2
Tc IN kg/YR
0.14
0.09
0.10
0.58
0.02
NIL
NIL
R
F

When RU/FP material was fed to the cascade, a portion of each constituent entered the cascade with the UF_6 while the balance remained in the cylinder. The split is assumed to be as shown in Table 2.2.5-1.

The barrier is assumed to contain essentially all of the TRU and was contaminated with Np, Pu, and ^{99}Tc at an estimated 0.24 ppm, 4 ppb, and 7 ppm, respectively, prior to FY 1967 and 0.09 ppm, 2.2 ppb, and 7 ppm, respectively, thereafter (Ref. 2) that was removed during the equipment change-out. This barrier was decontaminated in the X-705 large equipment tunnel, where essentially all of the TRU and ^{99}Tc was assumed to go into solution. This process removed essentially all Np and Pu from the PORTS cascade and approximately ½ of the ^{99}Tc introduced through FY 1959. The ^{99}Tc from the PPF is assumed to continue to absorb on cascade surfaces until it reaches equilibrium. No record of ^{99}Tc releases or its presence in the product were found to have occurred during this campaign.

3.1.2 Campaign #2

In Campaign #2, the barrier is again assumed to contain essentially all of the TRU and ^{99}Tc that was removed during the CIP/CUP and purge converter change-outs. The CIP/CUP change-out replaced equipment that contained the Np and Pu and a portion of the ^{99}Tc. The Np and Pu remain near the feed point, while ^{99}Tc may be found almost anywhere above the feed point. For this reason, only ^{99}Tc is shown as present in the purge converters changed-out. During this campaign, the barrier and other removed equipment were decontaminated. The TRU and ^{99}Tc are assumed to go into solution. The decontamination and processing of the decontamination solutions are assumed to have been performed in the same period as the equipment removal. All of the ^{99}Tc is assumed to go into the raffinate or traps. Ninety-nine percent of the Np and Pu are assumed to end up in the oxide produced.

Beginning with FY 1972, additional data on PPF became available and this was used to calculate the quantity of ^{99}Tc present. Starting with FY 1976, the product produced at PORTS is known to contain ^{99}Tc. An average of about 2% of the total amount of ^{99}Tc remaining in the cascade is estimated to be removed annually. It is estimated that a total of 1,585g of ^{99}Tc was removed in the product stream through March 1999. In FY 1975, quantities of ^{99}Tc that were detected in air/water releases to the environment were removed from PORTS inventory. The ^{99}Tc is shown as removed from PORTS inventory in the year the product is withdrawn from the cascade.

The HRT/SRT received in FY 1968 and 1969 was not all fed immediately. Therefore, the RU appears in the year-end inventory until fed. The TRU and ^{99}Tc fed to the cascade during this period is assumed to have been almost completely removed during the CIP/CUP program and/or purge converter change-out. No significant quantity of material is believed to have been removed during the 7A compressor change-out.

3.1.3 Campaigns #3 and #4

The UF_6 from the miscellaneous cascade feed and non-UF_6 scrap returns are summarized in the last two campaigns. The RU and contaminants are assumed to be fed or processed uniformly over the period from the earliest feed/processed date to the latest feed/processed date. Some of this material remains in storage.

3.2 Uranium Receipts

See Figure 3.1-1 and Table 3.2-1 for a summary of the RU received each FY and its source. A total of 1,123.7 MTU of RU (all forms) was received at PORTS. The table does not include Paducah or Oak Ridge product feed, which PORTS considers to be ^{99}Tc contaminated, but not RU. However, the mass flow includes the ^{99}Tc constituent of these PORTS feeds.

Table 3.2-1

PORTS Receipts Summary (RU Only)

		Net Weight (kgU)								
Shipping Facility	**Uranium Form**	**FY 1955**	**FY 1956**	**FY 1957**	**FY 1958**	**FY 1966**	**FY 1967**	**FY 1968**	**FY 1969**	**FY 1972**
Allied Chemical	UO_3									
Babcock & Wilcox	UF_6									
Division of International Affairs	UF_6							151		
	UNH					7	39			
Fernald	U_3O_8									
France	UF_6									65
Germany	UNH									
K-25	UF_4			865						
	UF_6		296, 504							
	UO_2			418						
	UO_3			3,319						
NUMEC	UF_6									330
Paducah	UF_6	105,873	54,649	6,156	64,311				567,620	
United Kingdom	UNH									
USAEC Office Safeguards & Materials. Management.	UF_6								2,833	
Y-12	U_3O_8									
Grand Total		**105,873**	**351,154**	**10,758**	**64,311**	**7**	**39**	**151**	**570,453**	**395**

Table 3.2-1 (Cont'd)

PORTS Receipts Summary (RU Only)

		Net Weight (kgU)							
Shipping Facility	**Uranium Form**	**FY 1973**	**FY 1974**	**FY 1975**	**FY 1976**	**FY 1976.5**	**FY 1977**	**FY 1978**	**Grand Total**
Allied Chemical	UO_3	1,376		1,403	1,295				4,074
Babcock & Wilcox	UF_6						153		153
Division of International Affairs	UF_6								151
	UNH								46
Fernald	U_3O_8				7,798				7,798
France	UF_6	202	324	128	273	112	152	235	1,586
Germany	UNH				6,860				6,860
K-25	UF_4								865
	UF_6								296,505
	UO_2								418
	UO_3								3,319
NUMEC	UF_6								330
Paducah	UF_6								798,609
United Kingdom	UNH			7					7
USAEC Office Safeguards & Materials. Management.	UF_6								2,833
Y-12	U_3O_8						104		104
Grand Total		**1,578**	**324**	**1,538**	**16,226**	**112**	**409**	**235**	**1,123,658**

3.3 Uranium Shipments

See Figure 3.1-1 and Table 3.3-1 for a summary by FY of the RU shipments from PORTS each FY and the receiving facility. PORTS shipped a total of 15.6 MTU of RU. The table does not include Paducah or Oak Ridge product feed, which PORTS considers to be ^{99}Tc contaminated, but not RU.

Table 3.3-1
PORTS Shipment Summary (RU Only)

Receiving Facility		Net Weight (kgU)						
	Uranium Form	FY 1955	FY 1956	FY 1972	FY 1974	FY 1982 - 1984	FY 1998	Grand Total
B&W	UO_3						800	800
France	UF_6			65				65
K-25	UF_6		3,102					3,102
NLO	U_3O_8					10,500		10,500
Paducah	UF_6	920	582		(368)			1,134
Grand Total		**920**	**3,684**	**65**	**(368)**	**10,500**	**800**	**15,601**

3.4 Recycled Uranium Waste

Central to the assumptions of this study is the concept of RU losing its identity through processing or treatment (i.e., the RU is blended with usually enormous amounts of non-RU resulting in product and tails streams containing deminimus quantities of RU). Wastes, therefore, are not classified as RU wastes, but rather wastes potentially contaminated with either TRU or FP. Such materials as alumina, NaF, and MgF_2 trapping media, contaminated pump oils, tower ash, and filter ash could constitute either waste or scrap depending upon the economics of processing and values of the recovered uranium. Holding pond and heavy metal sludges and ion exchange resins would constitute wastes from uranium recovery.

Quantification of the TRU/FP component of all of these streams could not be reliably accomplished within the time constraints of this report. Data on holding pond sludges have already been discussed. Data on filter ash have also been discussed. Some alumina and ion exchange resin data has been located, but not reviewed. NaF data remain to be discovered.

3.5 Recycled Uranium Scrap

For this study PORTS RU scrap is defined as RU scrap that was received from various sources either for conversion to UF_6 but was never converted to UF_6, or as RU-UF_6 feed that was never fed. Materials such as uranium heels in UF_6 cylinders that contained RU would meet this definition. There were 0.8 MTU of RU heels returned to PGDP and 0.8 MTU of RU heels returned to ORGDP. In addition, oxides (U_3O_8) produced from uranium recovery that contain TRU/FP could conceivably be considered RU scrap. In that regard, 0.85 MTU of highly enriched uranium oxides were shipped to BWXT during the HEU removal program. An unknown quantity of LEU oxides remain on site that potentially contain TRU/FP and may be considered scrap or waste depending upon the economics of processing and value of the recovered uranium.

3.6 Inventory as of March 31, 1999

A total of 8.3 MTU of RU (all forms) was in inventory at PORTS as of March 31, 1999. Table 3.6-1 shows the breakout by uranium form and includes the source of the material and the amount of uncertainty included in the inventory.

Table 3.6-1

PORTS March 31, 1999 Inventory of RU

Source Facility	Form	Amount Received (MTU)	Conv to UF_6 (MTU)	Conv to U_3O_8 (MTU)	UF_6 Fed to Cascade (MTU)	Amount Shipped (MTU)	Amount in Inventory 03/31/99 (MTU)	Inventory Uncertainty 03/31/99 (MTU)
Allied (ICPP)	UO_3	4.08	1.4		1.4	0.8	1.8	0.08
B&W	UF_6	0.15			0.15			0
Div. of I.A.	UF_6	0.15			0.15			0
	UNH	0.04						0.04
Fernald	U_3O_8	7.8	4.2		0.46	3.6	3.74	0
France	UF_6	1.6			1.1	0.01		0.4
Germany	UNH	6.9		6.9		6.9		0
NUMEC	UF_6	0.33			0.33			0
ORGDP	UF_4	0.86						0.86
	UF_6	296.5			293.4	3.1		0
	UO_2	0.4						0.4
	UO_3	3.3						3.3
PGDP	UF_6	798.6			797.5	1.1		0
USAEC	UF_6	2.8			0.07		2.73	0
Y-12	U_3O_8	0.1						0.1
TOTAL		**1123.61**	**5.6**	**6.9**	**1094.56**	**15.6**	**8.27**	**5.18**